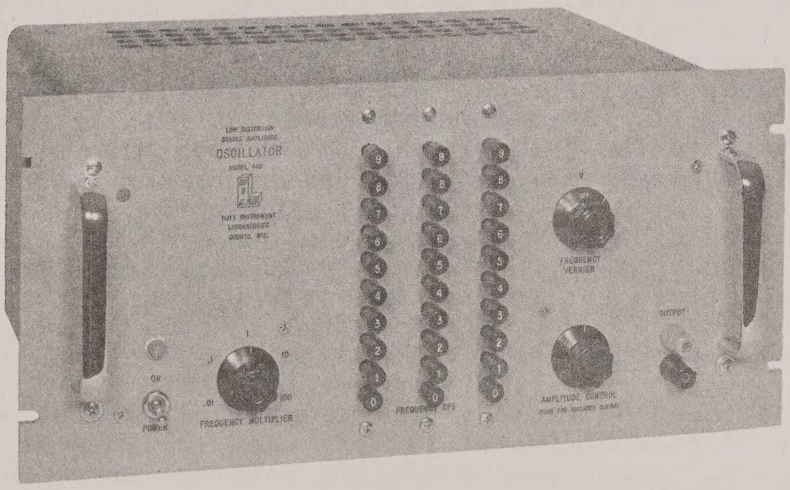
PRECISION

HOLT
INSTRUMENT
LABORATORIES
OCONTO WISCONSIN

MEASUREMENT

INSTRUCTION MANUAL
FOR
AUDIO OSCILLATOR
MODEL 448



This Manual to Accompany Serial No._____

HOLT INSTRUMENT LABORATORIES

OCONTO, WISCONSIN

MARCH 1963 EDITION

CLAIM FOR DAMAGE SHIPMENT:

The instrument should be tested as soon as it is received. If it fails to operate properly, or it is damaged in any way, a claim should be filed with the carrier. Also, notify Holt Instrument Laboratories or the local representative immediately. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY:

Holt Instrument Laboratories warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid, and when upon our examination it is to our satisfaction defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify either the factory or the area Holt representative, giving full details of the difficulty, and include the model and serial numbers. Upon receipt of this information we will give you service data or shipping instructions.

2. On the receipt of shipping instructions, forward the instrument prepaid to the factory or the authorized repair station indicated in the instructions. If requested, an estimate of the charges will be made before the work begins if such work is not covered by warranty. All shipments of Holt Instrument Laboratories' equipment should be packed in a strong exterior container surrounded by two or three inches of shock absorbing material.

TABLE OF CONTENTS

Page

Frontispiece

Warranty

Table of Contents

Technical Specifications

Section I Description 1
- 1-1 General Description 1
- 1-2 Oscillator Theory 2
- 1-3 Power Supply Circuits 3
- 1-4 Main Amplifier 4
- 1-5 AVC Amplifier 4

Section II Operating Procedures 6
- 2-1 Operation 6

Section III Servicing 8
- 3-1 General 8
- 3-2 Power Supply 8
- 3-3 Main Amplifier 9
- 3-4 AVC Amplifier 10
- 3-5 Bridged T Network 11
- 3-6 Voltage Measurement 14
  - 3-6.1 DC Voltage Measurement 14
  - 3-6.2 Heater Voltages and Ripple 15

Section IV Calibration and Adjustment 16
- 4-1 General 16
- 4-2 Special Equipment Required 16
  - 4-2.1 Frequency Counter 16
  - 4-2.2 Distortion Analyzer 16
  - 4-2.3 Amplitude Stability Test Unit 17
- 4-3 Frequency Calibration 18
  - 4-3.1 Decade Switch Calibration 18
  - 4-3.2 Frequency Stability vs. Line Voltage 20
  - 4-3.3 Frequency Vernier Check 20
- 4-4 Distortion Measurement 21
  - 4-4.1 AVC Amplifier Distortion 21
  - 4-4.2 Output Amplifier Distortion 21
  - 4-4.3 Oscillator Distortion 21
- 4-5 Hum Content 21
- 4-6 Amplitude Stability 21
  - 4-6.1 General Stability 22
  - 4-6.2 Amplitude Stability vs. Line Voltage 22
  - 4-6.3 Hum Modulation 22

Section V Replaceable Parts
- 5-1 Index of Manufacturers
- 5-2 Table of Replaceable Parts

Index of Illustrations

Fig. No.		Page
1	Simplified Block Diagram	2a
2	Table of Network Resistance Values	10a
3	Top View	12a
4	Bottom View	12b
5	Table of Voltage and Reiistance Measurements	14a
32261C	Schematic	

TECHNICAL SPECIFICATIONS

FREQUENCY RANGE:

1 cps to 100 KC
Continuously adjustable by 3 decade switches and a vernier potentiometer.

Band	Multiplier	Frequency (cps)
1	1/100	1-10
2	1/10	10-100
3	1	100-1000
4	10	1000-10,000
5	100	10,000-100,000

FREQUENCY CALIBRATION:

After 60 minute warmup:
± 1% from 10 cps to 10 KC
± 3% 1 cps to 10 cps and 10 KC to 100 KC

FREQUENCY STABILITY:

After 60 minute warmup:
± .05% per hour 1 cps to 10 KC
± 0.5% per hour 10 KC to 100 KC

FREQUENCY REGULATION:

For a ± 10% change in line voltage:
± 0.03% 1 cps to 10 KC
± 0.2% 10 KC to 100 KC

AMPLITUDE STABILITY:

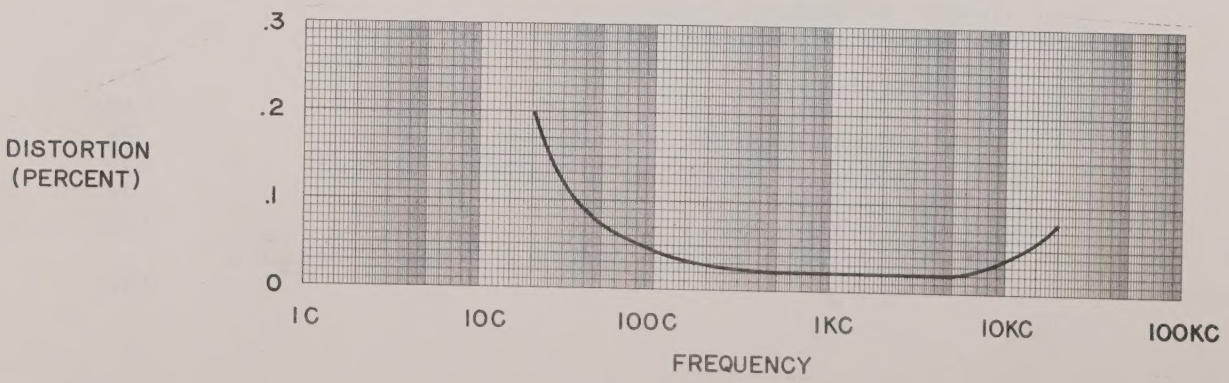
Short term (1 second to 10 seconds):
± 0.01% random variations
Beat frequency modulation:
0.1% near line frequency
Low frequency modulation, f_m,
($1 < f_m < 200$ cps)
0.03% 35 cps to 500 cps
0.05% 500 cps to 2 KC
0.1% 2 KC to 10 KC
0.15% 10 KC to 20 KC

AMPLITUDE REGULATION:

Line voltage change:
± 0.005% for a 10% line change within operating range.
Frequency change:
± 0.01 db (0.1%) 10 cps to 20 KC
± 0.05 db (.5%) 20 KC to 100 KC
± 0.5 db (6%) 1 cps to 10 cps

HARMONIC DISTORTION:

Total Harmonic Distortion:



1% 1 cps to 20 cps and 20 KC to 100 KC

HUM AND NOISE:	0.02% at any output level setting
OUTPUT VOLTAGE:	Direct - 1 cps to 100 KC: 10 volts RMS open circuit 9 volts RMS into a 2000 ohm load Isolated - 35 cps to 20 KC: 1.1 volts RMS open circuit 1 volt RMS into a 100 ohm load
OUTPUT POWER:	40 milliwatts maximum
INPUT POWER:	115 V ± 10%, 50-60 cycles, 120 watts
SIZE:	19" W X 8-3/4" H X 15" D
WEIGHT:	55 lbs. shipping
PRICE:	$1540.00 Rack Mount, Bench Cabinet Additional

SECTION I

DESCRIPTION

1-1 General Description

The Model 448 Push-Button Oscillator is designed for applications requiring very low distortion or good amplitude and frequency stability. It provides sine waves at any frequency between 1 and 100,000 cycles per second. It operates from an AC source of 105 to 125 volts, 50-60 cycles per second. An integral power supply furnishes the heater voltages and regulated voltages required for operation.

As shown in the simplified block diagram, Figure 1, the Oscillator is a resistance-capacitance type using a modified "Bridged T" RC network as the frequency determining circuit. The resistive elements in the RC network are varied by the three banks of ten push-button switches to provide fine control of frequency. Coarse control of frequency is obtained by the frequency multiplier switch which selects the required value of both capacitors in the RC network. A vernier frequency control varies the frequency continuously by an amount equal to the increment between adjacent buttons of the third switch bank with additional frequency overlap beyond 10 on the vernier dial.

The main and AVC amplifiers provide the required signals for the RC network. Amplitude stability is maintained by the AVC amplifier which uses a thermistor as a voltage sensitive device in a resistance bridge.

The output is controlled by a logarithmically tapered potentiometer directly on the output to maintain hum and distortion in constant ratio to the output voltage. The output selector switch permits selection of either a high level, high impedance,

direct output from 1 cps to 100 KC or a low level, low impedance, isolated output from 35 cps to 20 KC.

1-2 Oscillator Theory

There are two essential requirements that must be realized in any oscillator in order to generate low distortion oscillations with constant amplitude. The internal loop gain must be regenerative with zero phase shift at the frequency of oscillation, and at this frequency the gain must be precisely equal to unity.

If the internal loop gain is greater than unity by any finite amount, the amplitude of oscillation will build up until it saturates the amplifier. Or if the internal loop gain is less than unity, the amplitude of oscillation will diminish to zero.

If the phase shift in the amplifier at the resonant frequency deviates from zero, the frequency of oscillation will no longer be determined entirely by the RC network parameters. Since the requirements for zero phase shift must be maintained in the internal loop, the frequency of oscillation will be "pulled" to satisfy the necessary conditions of zero phase shift.

This frequency "pulling" is minimized by using high gain, wide band amplification to provide a steep rate of change of phase shift about the resonant frequency.

The AVC Amplifier and the voltage sensitive device, RT102, maintain the gain precisely at unity, independent of variations in the internal loop gain. The voltage sensitive device is a thermistor whose resistance is inversely proportional to the dissipated power. Since the power across the thermistor is obtained directly from the oscillator output, the resistance of the thermistor is inversely proportional to the amplitude to oscillation. Because the

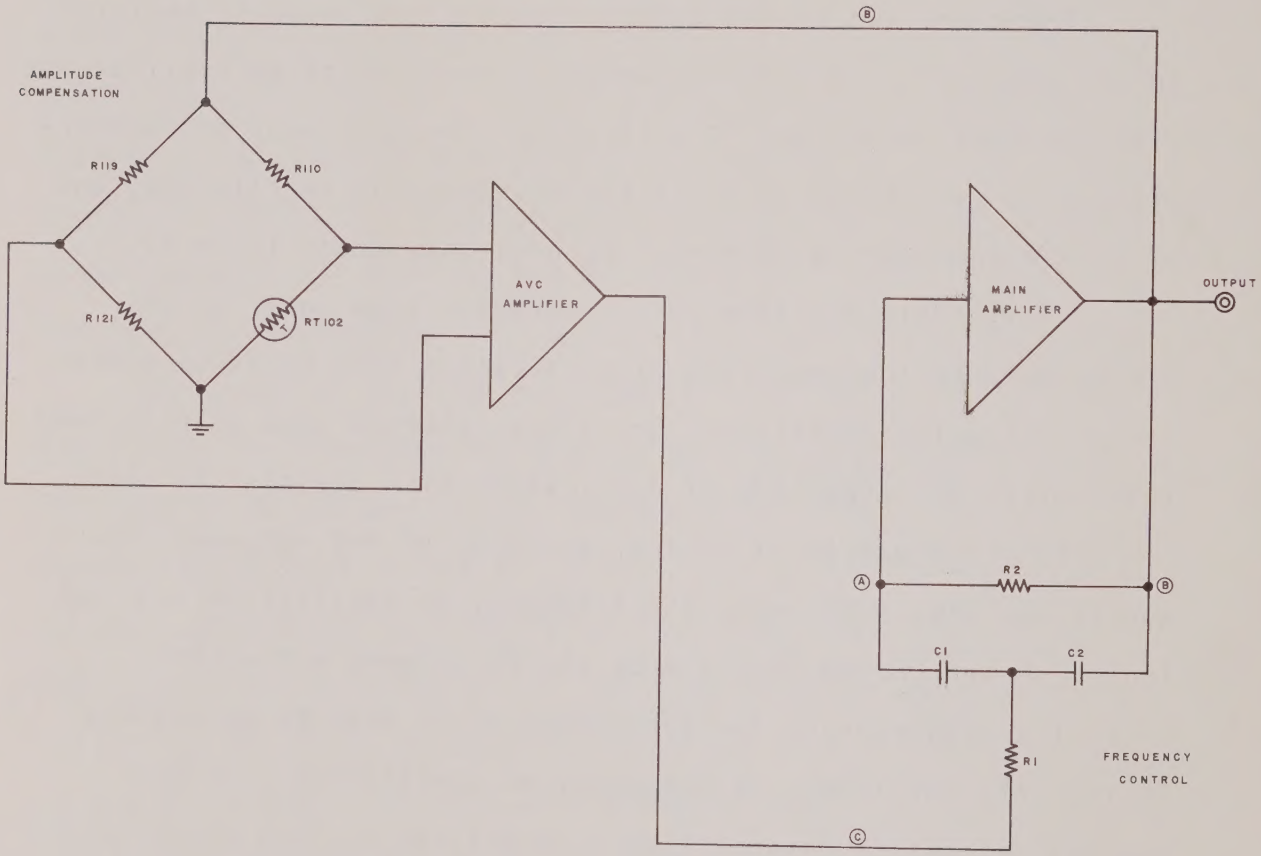


Figure 1

SIMPLIFIED BLOCK DIAGRAM

thermistor is the only voltage sensitive device in the AVC circuit, the amplitude of oscillation must adjust itself until the gain precisely equals unity.

The operation of the AVC amplifier and the voltage sensitive device may be understood more easily, for example, if we assume that the output amplitude of the oscillator decreases due to a decrease in the gain of the main amplifier. This results in a proportional decrease in the signal at the grid of V1B. The signal at the grid of V1A will decrease less than the one at V1B because the resistance of the voltage sensitive element, RT102, will increase with decreasing output voltage. The error voltage, resulting from this differential decrease in amplitude, is amplified by the AVC amplifier and increases the output of the AVC amplifier. This error voltage appearing at the output of the AVC amplifier restores the amplitude to approximately its original level.

1-3 Power Supply Circuits

The oscillator has three power supplies - one unregulated supply and two electronically regulated supplies. The unregulated supply uses a full wave rectifier tube V9 whose output is filtered by a capacitor input single section pi filter consisting of C401, C402 and L401.

One electronically regulated supply, using tubes V10, V11 and V12 and referred to as the Regulated Supply, provides 350 volts. The other electronically regulated supply consists of tubes V13 and V14 and is referred to as the Center-Tap Regulator.

The Center-Tap Regulator adds the negative and positive of the 350 volt regulated supply through two resistors R410 and R413 and compares the sum with chassis ground in a differential amplifer

V13. Since the comparison resistors are effectively equal and the reference voltage is chassis ground, the regulated 350 volts is divided into two balanced or equal and opposite voltages, +175 and -175 volts with respect to ground. The output of V13 is coupled to V14 which acts as a variable resistance to compensate for load variations in either the +175 or -175 volt busses.

1-4 Main Amplifier

The main amplifier consisting of tubes V5, V6, V7 and V8 sustains the oscillations at the frequency determined by the RC network and provides the gain necessary for harmonic degeneration.

The output of the RC network is fed to the first stage of the main amplifier V5B. A balanced input amplifier is used in the first stage to reduce drift in the DC output level with variations in line voltage. Another cathode coupled amplifier consisting of V6 and V7 provides the additional gain necessary to maintain the specified distortion and amplitude stability. The second amplifier drives the output amplifier V8 which operates as a cathode follower to deliver the rated power output. The transistor Q601 acts as a DC clamp for the output circuit.

1-5 AVC Amplifier

The AVC Amplifier consisting of tubes V1, V2, V3 and V4 maintains the amplitude of oscillation very nearly constant independent of frequency. The operation of the AVC amplifier can be understood more easily be referring to the simplified block diagram shown in Figure 1.

The basic amplitude discriminator is a bridge whose four resistance arms consist of R119, R121, R110 and RT102, a thermistor

operating as a voltage sensitive element. The bridge is driven from the output of the main amplifier, and the output of the bridge is amplified in the differential input amplifier, V1.

The second stage of amplification, V2, provides the additional gain to maintain low distortion. The output of V2 drives the output amplifier V3, which functions as a cathode follower to maintain the AVC signal at its required impedance level. The overall gain of the AVC amplifier is maintained very nearly constant by feeding back degeneratively a portion of the output signal via R133 to the input amplifier V1. Additional AVC action is provided by V4 when excessive signals are encountered in the AVC amplifier.

SECTION II

OPERATING PROCEDURE

2-1 Operation

The oscillator is checked carefully in final test to insure that it meets all its specifications. It is operated continuously for not less than 48 hours and again tested before shipment to insure that the instrument is ready for use. Although the oscillator is easy to operate, it depends for its ultimate performance on the thermal oven. A one hour warmup period should be allowed to insure best operation. Reasonable performance may be expected after as short a period as 15 minutes, but a warmup period of less than this can result in excessive distortion.

The desired frequency is selected by the three banks of ten push-button switches and reads directly in cycles per second times the multiplying factor when the frequency vernier control is turned maximum clockwise to the OFF position. For maximum frequency accuracy, the first row of push button switches should not be set to zero. The frequency multiplier switch selects the proper multiplying factor for all the five bands. IMPORTANT! The oscillator will not operate unless one button in each of the three push-button switches is engaged.

The amplitude control adjusts the output level in two modes of operation. With the control in "direct" position, a maximum of ten volts RMS will be developed into an open circuit, or 9 volts RMS across a 2000 ohm load, from 1 cps to 100 KC. 2000 ohms is specified as the minimum load impedance in the "direct" position to insure low distortion when the amplitude control is at or near the maximum setting, although a lower impedance load will not damage the instrument. When the amplitude

control is operated at reduced level, a lower impedance may be used without increasing the distortion.

With the amplitude control in "isolated" position, the output is isolated from the oscillator by means of a 10:1 transformer. The maximum output in this position is 1.1 volts RMS into an open circuit, or 1 volt RMS into a 100 ohm load, in the frequency range from 35 cycles to 20 KC.

SECTION III

SERVICING

3-1 General

If the oscillator blows fuses, replace the 5V4 rectifier tube and check for short circuits in the unregulated and regulated voltage busses and the 4MFD filter capacitors C401 and C402.

If the oscillator has no output, the likeliest source of failure is the vacuum tubes. Obtain new tubes and substitute them one at a time in the oscillator.

3-2 Power Supply

Check the +330 volt buss which is referred to ground and not to the center tap of the high voltage secondary which is normally at -175 volts with respect to ground. If this unregulated voltage deviates from its proper value, replace the rectifier, V9. If replacing V9 brings about no change in the voltage level, check the total current drain by measuring the voltage across L401 which under normal conditions should measure 20 volts.

Check the regulated supply voltages which should be +175 $\pm$ 5 volts and -175 $\pm$ 5 volts. The +175 volt regulated buss can be checked at Pin 3 of V10 and the -175 volt regulated buss at the negative terminal of the 4MFD filter capacitors, C401 or C402. It is worth emphasizing again that the center-tap regulator normally divides the regulated +350 volt supply into two balanced voltages. If the regulated supply puts out 300 volts instead of the normal 350 volts, the center-tap regulator, if functioning properly, will divide the 300 volts into two equal and opposite voltages, +150 and -150 volts with respect to chassis ground.

When the output of the center-tap regulator is balanced, irrespective of the magnitude of the voltages, the center-tap regulator is functioning properly.

It is possible that an unbalanced condition may be due to a malfunction not originating in the center-tap regulator. An excessive unbalance in the current drain due to a malfunction in the main or AVC amplifier can prevent the center-tap regulator from operating properly. Under this condition, since the operating voltages are incorrect, the main and AVC amplifier can be tested only by checking their resistance to ground.

3-3 Main Amplifier

Measure the output DC level of the main amplifier at Pin 3 of V8. It should be zero $\pm$ 1 volt. If this level is incorrect adjust the output DC level control P202 at the rear of the chassis. The output DC level is maintained at this value because it is compared with ground in the differential amplifier V5.

There are two likely malfunctions that might occur outside the main amplifier that would result in an incorrect output DC level even though the main amplifier is functioning properly. When the sine wave output is excessively distorted or the DC path in the RC network is interrupted, the output DC level of the main amplifier will differ from its normal value. Before checking the main amplifier it is advisable to eliminate the possibility of these two malfunctions. Excessive sine wave amplitude can be eliminated by stopping the oscillator from functioning. Switch the frequency multiplier control to 100, set the frequency to 10,000 cps, and connect a 0.1 MFD capacitor from the control grid of V8 to ground. If the output DC level returns

to its normal value, 0 ± 1 volt, the level determining components in the main amplifier are functioning properly and the trouble is probably in the AVC amplifier. If the output DC level does not return to its proper value, check the possibility of an open circuit in the DC path of the RC network. Short circuit the RC network by connecting a jumper from the output of the main amplifier V8 Pin 3 to the input of the main amplifier V5 Pin 2. Check the output DC level of the main amplifier with the jumper and the 0.1 MFD capacitor connected. If the level returns to its normal value, this indicates a malfunction in the RC network. If the output DC level does not return to its normal value when the jumper is connected, the main amplifier is not functioning properly.

3-4 AVC Amplifier

Measure the output DC level of the AVC amplifier at Pin 8 of V3. It should be zero ± 1 volt. If this level is incorrect adjust the AVC amplifier DC level control P102 at the test point at the rear of the chassis. Since the bridge on the input of the AVC amplifier is direct coupled to the output of the main amplifier, it is important that the output of the main amplifier be at its correct DC level before checking the output DC level of the AVC amplifier. To eliminate the possibility of introducing an unwanted signal into the AVC amplifier which may upset the output DC level, it is desirable that a 0.1 MFD capacitor be connected from the grid of output amplifier V8 to ground. The frequency multiplier control should be switched to 100, and the oscillator should be set at a frequency of 10,000 cps.

The oscillator output voltage is determined by the fixed, factory selected bridge components located within the oven. The

AVC amplifier gain control, P101, is critically adjusted at the factory for maximum AVC gain with a certain amount of bridged T network unbalance that is specifically introduced for this adjustment. This control should not require any further adjustment; it has no effect on output level, and it must not be used to adjust for minimum signal distortion. If the output distortion is excessive, select a new tube for V1. If the voltages are correct and new tubes do not improve distortion, there is a possibility that a component in the oven has become defective. In this case, the oven should be returned to the factory for repair or replacement.

If the oscillator exhibits a tendency to generate spurious signals or does not function properly on the high frequency ranges, the high frequency bypass capacitors C101 to C106 in the AVC amplifier, or C201 through C210 in the main amplifier may be open circuited and should be checked. This can be done by shunting a capacitor of the same value across them directly without removing the capacitor in the oscillator. If the performance of the oscillator changes appreciably when a capacitor is by-passed it is probably defective and should be replaced.

3-5 Bridged-T Network

If the oscillator is operating erratically on some bands or the frequency calibration deviates from its indicated value, the frequency multiplier band switch, the push-button switches or the frequency determining parameters of the network may be defective. If the contacts on all the switches are excessively dirty, direct a stream of compressed air at them and then check each contact with an ohmmeter.

Sw. Pos.	S-301 Units R_2	S-301 Units R_1	S-302 Tens R_2	S-302 Tens R_1	S-303 Hundreds R_2	S-303 Hundreds R_1
9	564.2K ±1% R307 R308 R309	56.42K ±1% R317 R318 R319	55.97K ±1% R327 R328 R329	5.59K ±1% R337 R338 R339	5.597K ±½% R347 R348 R349	557 Ω ±½% R357 R358 R359
8	635.2K ±1% R306 R307 R308	63.52K ±1% R316 R317 R318	62.95K ±1% R326 R327 R328	6.295K ±1% R336 R337 R338	6.295K ±½% R346 R347 R348	627 Ω ±½% R356 R357 R358
7	726.8K ±1% R305 R306 R307	72.68K ±1% R315 R316 R317	71.94K ±1% R325 R326 R327	7.194K ±1% R335 R336 R337	7.194K ±½% R345 R346 R347	717.2 Ω ±½% R355 R356 R357
6	849.4K ±1% R304 R305 R306	84.94K ±1% R314 R315 R316	83.93K ±1% R324 R325 R326	8.393K ±1% R334 R335 R336	8.393K ±½% R344 R345 R346	837.3 Ω ±½% R354 R355 R356
5	1.022M ±1% R303 R304 R305	102.2K ±1% R313 R314 R315	100.7K ±1% R323 R324 R325	10.07K ±1% R333 R334 R335	10.07K ±½% R343 R344 R345	1.005K ±½% R353 R354 R355
4	1.282M ±1% R302 R303 R304	128.2K ±1% R312 R313 R314	125.9K ±1% R322 R323 R324	12.59K ±1% R332 R333 R334	12.59K ±½% R342 R343 R344	1.257K ±½% R352 R353 R354
3	1.72M ±1% R301 R302 R303	172K ±1% R311 R312 R313	167.9K ±1% R321 R322 R323	16.79K ±1% R331 R332 R333	16.79K ±½% R341 R342 R343	1.677K ±½% R351 R352 R353
2	2.611M ±1% R301 R302	261.1K ±1% R311 R312	251.8K ±1% R321 R322	25.18K ±1% R331 R332	25.18K ±½% R341 R342	2.515K ±½% R351 R352
1	5.423M ±1% R301	542.3K ±1% R311	506K ±1% R321	50.6K ±1% R331	50.36K ±½% R341	5.03K ±½% R351

Figure 2

TABLE OF NETWORK RESISTANCE VALUES

As shown in the simplified block diagram, Figure 1, the RC network consists basically of two precision resistors and capacitors. The effective resistances R1 and R2 are varied by the three banks of ten push-button switches, and the capacitors C1 and C2 are varied by the frequency multiplier switch.

The indicated resistances as shown in Figure 2 are the correct values of R1 and R2 when only one push-button in any bank of ten push-button switches is operated and the other two banks are switched to the zero position. To measure the effective value of the precision resistors R1 and R2, all of which are wired to the push-button switches directly, it is necessary to disconnect two non-precision resistors R364 and R365, located on the under chassis as shown in the bottom view, Figure 4. These two resistors operate in conjunction with the RC network and the frequency vernier.

The effective value of R2 can be measured by connecting a suitable DC resistance bridge from the output of the main amplifier V8 Pin 3 to the input of the main amplifier V5 Pin 2. The effective value of R1 can be measured from the output of the AVC amplifier V3 Pin 8 to the junction point can be located most easily at the pole on the back section of the frequency multiplier band switch. A wire connects this junction point to the adjacent push-button switch. During these measurements the frequency multiplier switch should be switched to the 100 position of the frequency multiplier.

If the measured resistance differs from the indicated resistance as shown in Figure 5, the defective resistor cannot be isolated immediately because the precision resistors are operated

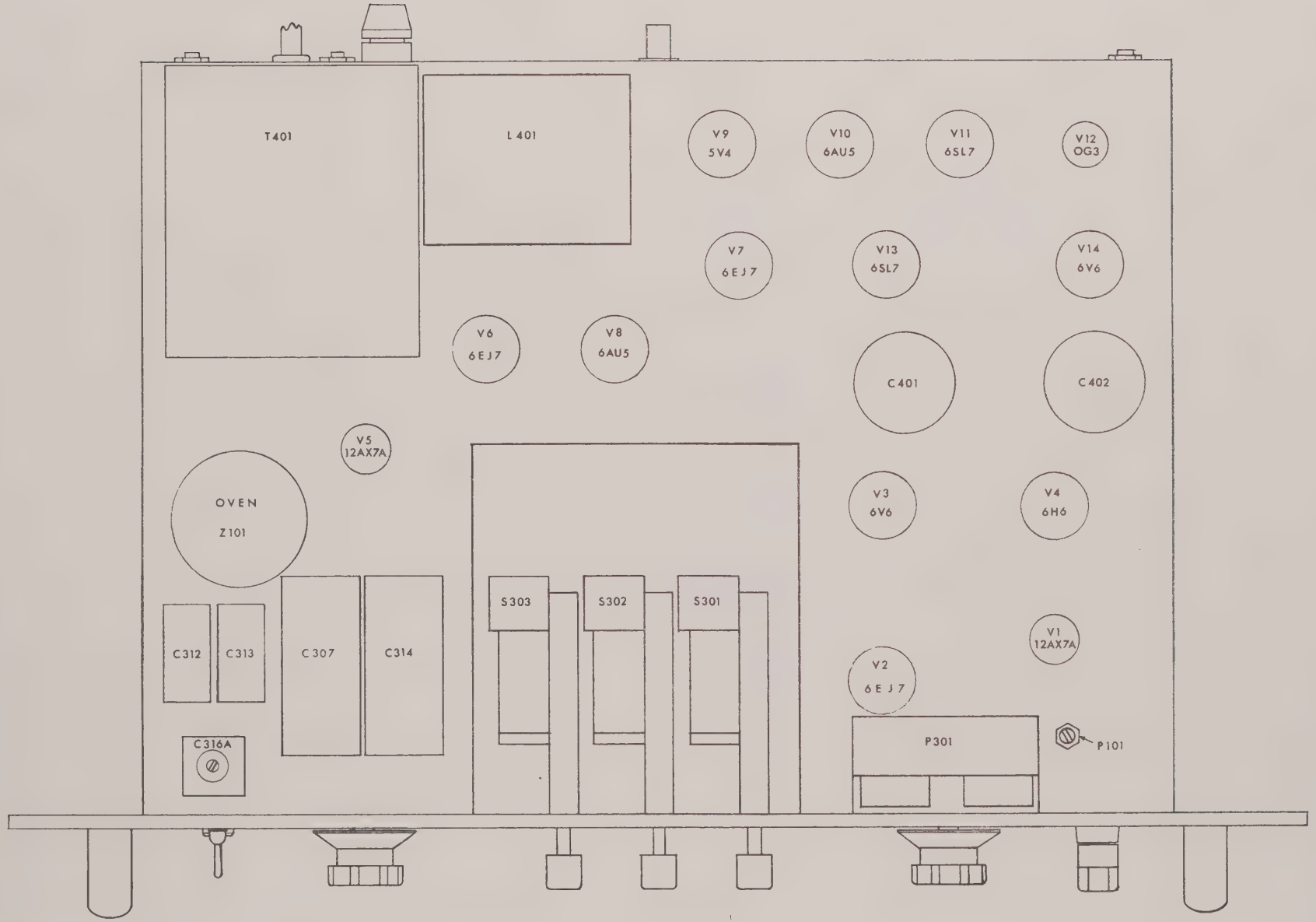


Figure 3

TOP VIEW

in parallel. The precision resistors which may be defective when the indicated and measured resistors are in disagreement are listed below the correct values of R1 and R2. When a discrepancy occurs between the measured value and the correct value of R1 and R2, any one or all of the precision resistors listed below the correct value may be defective. Since most of the precision resistors are common to three push-buttons, a defective resistor can be isolated if the indicated and measured values of any three adjacent push-buttons on one bank are in disagreement. The defective resistor will be the one common to all three push-buttons.

The values of the precision capacitors, C307 through C316 are shown on the schematic and can be checked with a suitable impedance bridge without disconnecting any leads or components. All of the capacitors can be checked on the 0.01 position of the frequency multiplier excepting C307 and C314, which should be checked on the 0.1 switch position.

If a frequency determining capacitor, C307 through C316, should become defective and require replacement, a matched pair of capacitors should be ordered from the factory. Both corresponding capacitor arms in the RC network should be replaced with the factory pre-selected values so that the frequency calibration and the output amplitude will be correct.

Note that although the AVC bridge components establish the output level, an unbalanced condition in the bridged T network will also affect the output amplitude. The AVC amplifier will correct for some slight unbalance in the bridged T network. However, a larger unbalance will cause the AVC amplifier to be operated at its design limits, resulting in excessive distortion

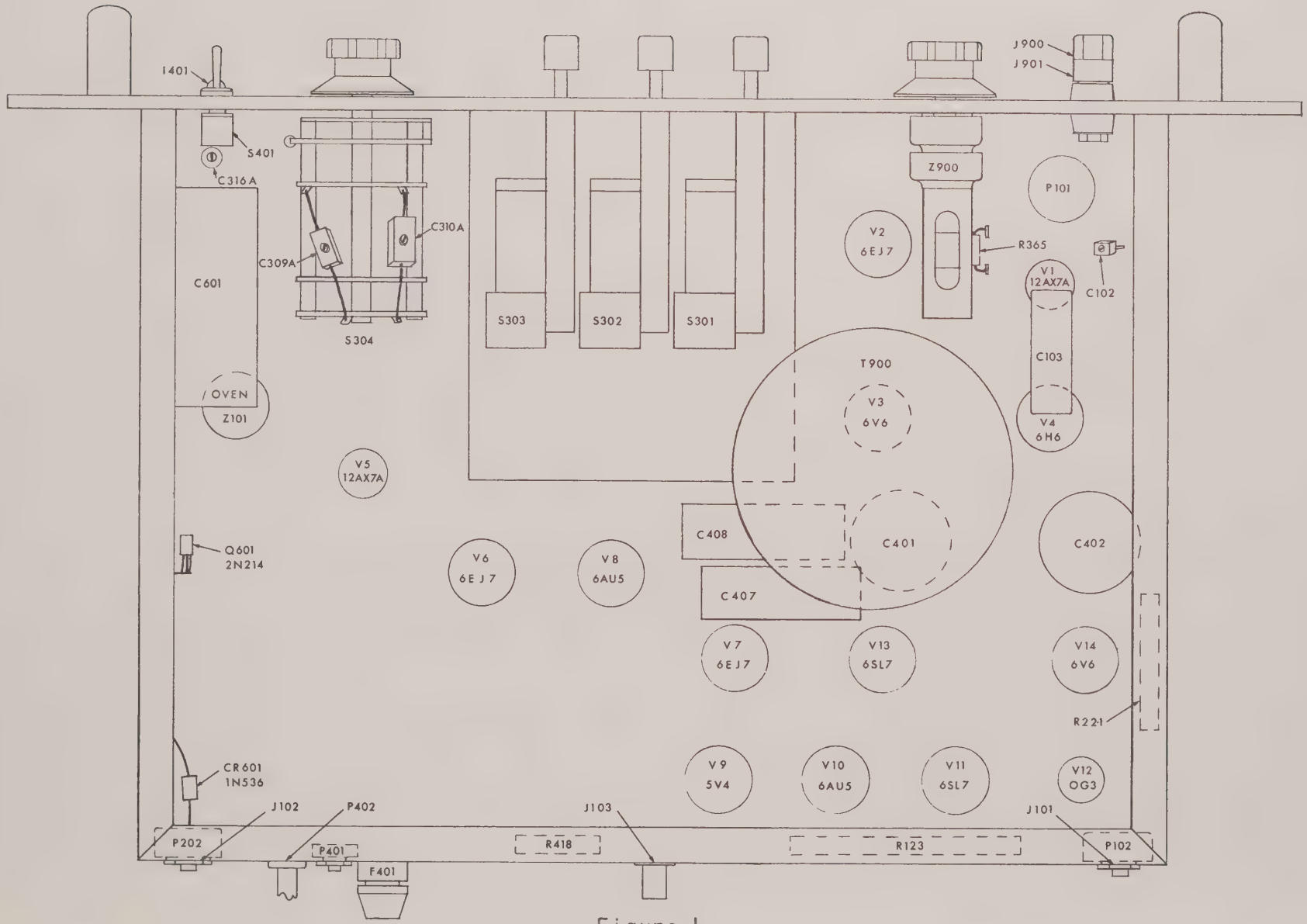


Figure 4

BOTTOM VIEW

and high output amplitude on some ranges.

3-6 Voltage Measurement

All measurements are made with a line voltage of 115 volts, unless otherwise specified.

3-6.1 DC Voltage Measurement

All DC voltage measurements are to be made with a vacuum tube voltmeter, and are made with respect to ground (chassis), unless otherwise specified. A comprehensive tube voltage chart is shown in Figure 5.

	Voltage Check	Check Point	Tolerance	Possible Remedy
A.	B minus	Negative end of C402	-170 to -184 volts	Check V12(0G3) or R407 and R408
B.	B plus	Pin 4 of V14 (6V6)	Within ± 2 volts from step A, but opposite polarity	Check R410 and R413
C.	1st AVC stage	Pin 1 of V1 (12AX7A)	+140 to +160 volts	Check R101 and R106
D.	Output DC Level	Sine wave output terminal	± 0.1 volt	Adjust P202 (output DC level adjust)
E.	AVC DC Level	Pin 8 of V3 (6V6)	± 1.0 volt	Adjust P102 (AVC DC level adjust)
F.	2nd AVC stage	Pin 8 of V2 (6AC7)	+115 to +135 volts	Check R117 and R121
G.	Diode minus	Pin 3 of V4 (6H6)	-5 to -12 volts	V4 components
H.	Diode plus	Pin 5 of V4 (6H6) to Pin 8 of V3 (6V6)	+0.05 to -4 volts	V4 components
I.	Unregulated B+	Pin 5 of V10 (6AU5)	+315 to +335 volts	Check V9
J.	2nd stage of Main Amplifier	Pin 8 of V6 (6AC7)	+90 to +100 volts	Check R213

Voltages measured between the pins of each socket and chassis. The meter used for the measurements was a V.T.V.M. with an impedance of 11 megohms. All measurements were made with the Frequency Multiplier on 100 at a frequency of 10,000 cps and 115 volt line.

Resistances measured in the same manner except with line cord removed.

Variations up to ± 20% to be expected.

All resistances in ohms. K = 1000 M = 1,000,000

TUBE NO.		PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8	PIN 9
V1	V	150	0±1	1.2	-3	-3	110	0±1	1.4	-3
12AX7A	R	48K	2.2K	200K±50K	2.2K	2.2K	250K	1.4K	200±50K	2.2
V2	V	0	-3	0	-3	0	175	-3	125	--
6AC7	R	0	2.2K	0	1.2M	0	30K	2.2K	40K	--
V3	V	0	-3	330	175	-72	0±1	-3	0±1	--
6V6	R	0	2.2K	1M	30K	520K	50K	2.2K	6K	--
V4	V	0	-3	-10	0	0	0	-3	0	--
6H6	R	0	2.2K	80K	0	54K	54K	2.2K	0	--
V5	V	110	0	1.1	-3	-3	108	0±1	1.3	-3
12AX7A	R	240K	0	350K±50K	2.2K	2.2K	220K	50K	350K±50K	2.2
V6	V	0	-3	-55	-57	-55	42	-3	100	--
6AC7	R	0	2.2K	17K	850K	17K	14K	2.2K	55K	--
V7	V	0	-3	-55	-57	-55	42	-3	0	--
6AC7	R	0	2.2K	17K	39K	17K	14K	2.2K	0	--
V8	V	-26	-3	0±1	0±1	110	-26	-3	175	--
6AU5	R	440K	2.2K	1K	1K	1M	440K	2.2K	30K	--
V9	V	--	330	--	-180	--	-180	330	330	--
5V4	R	--	1M	--	2.2K	--	2.2K	1M	1M	--
V10	V	140	175	175	110	315	175	175	315	--
6AU5	R	1.5M	30K	30K	245K	1M	2.2K	30K	1M	--
V11	V	-2	140	0	-85	110	-85	-3	-3	--
6SL7	R	850K	1.5M	0	165K	240K	19K	2.2K	2.2K	--
V12	V	--	-85	0	-85	0	--	-85	--	--
OG3	R	--	19K	0	19K	0	--	19K	--	--
V13	V	0	110	2	0±1	175	2	-3	-3	--
6SL7	R	0	220K	560K	80K	30K	560K	2.2K	2.2K	--
V14	V	0	-3	330	175	-4.6	--	-3	0	--
6V6	R	0	2.2K	1M	30K	850K	--	2.2K	0	--

Table of Voltage and Resistance Measurements
Model 448

Figure 5.

3-6.2 Heater Voltages and Ripple

A. Read the AC voltage across Pins 4 and 9 of V1 (12AX7A). Tolerance: 4.6 to 5.4 volts.

B. Read the AC voltage across Pins 2 and 7 of V2 (6AC7). Tolerance: 5.7 to 6.9 volts.

C. Measure the AC ripple from the center arm of P401 (hum adjust potentiometer) to ground. Tolerance: Less than 200 millivolts. If incorrect, check for a ground in the heater wiring.

SECTION IV

CALIBRATION AND ADJUSTMENT

4-1 General

The steps outlined in this procedure follow very closely the operations which are performed on the instrument by the final test department, and following this procedure should restore the instrument to its original operating efficiency and accuracy. If any difficulties are encountered or any questions arise which are not covered by this procedure, please consult the factory service department.

4-2 Special Equipment Required

4-2.1 Frequency Counter

A precision frequency counter which is capable of measuring frequency from one cps to 100 KC is required.

4-2.2 Distortion Analyzer

A distortion meter or wave analyzer capable of measuring distortion below 0.01% from 20 cps to 20 KC is required.

Note that it is difficult to measure very low levels of distortion with commercial distortion or wave analyzers because these instruments usually have an internal amplifier which inherently adds some noise to the distortion reading. Care must be taken that these instruments are properly calibrated and that the analyzer hum balance controls have been critically adjusted. Also check that no distortion reading is observed on any range when the input terminals are shorted.

At very low distortion levels the phase relationship between input harmonic voltages and those generated within a distortion analyzer become important because the panel meter indicates the magnitude of the vector sum of these voltages. Depending on

relative phase and amplitude, an input harmonic voltage could produce a distortion anywhere from zero to many times its actual value.

The distortion analyzer sensitivity or input signal level must not be increased independently in an attempt to obtain a better harmonic voltage amplitude or percentage reading. The input circuits of the analyzer would thus be overloaded by the fundamental frequency voltage and the resulting distortion will lead to erroneous readings even though the meter appears to be functioning properly.

In order to measure accurately the very low level of harmonic distortion in the output signal, special distortion filters were developed in the factory. These filters have a null or rejection frequency which is tuned to the oscillator frequency. The fundamental frequency is therefore removed but the harmonics are passed at full gain (40 db) up to and including the fifth harmonic. A relatively broad null is used at the rejection frequency so that small changes in the input frequency do not disturb the distortion reading. The total RMS harmonic distortion is measured and compared with the oscillator input signal to obtain the percent harmonic distortion.

4-2.3 Amplitude Stability Test Unit

An amplitude stability test unit such as the Holt Model 52, which is capable of measuring instability below 0.01% is required.

This particular test unit was designed specifically for measuring very small changes in the amplitude of the AC voltage output of the oscillator. One practical definition of short term amplitude stability relates to the sensitivity characteristics of voltmeters to be calibrated with a voltage source. It was found

that some voltemeters measured variations up to 9 cps (110 ms). There are also available commercially some AC voltage regulators which smooth out variations below 0.7 cps (1.5 sec). Therefore, it is required that the oscillator be stable at least between 1.5 seconds to 110 milliseconds.

In this test unit, the AC voltage is applied to a passive network consisting of a full-wave rectifier and two filters which have time constants of 1.5 seconds and 110 milliseconds respectively. The output is the difference between these two filtered voltages and should be observed with an oscilloscope to eliminate readout time lag. Thus, if the signal amplitude changes slowly, the trace will remain steady on the oscilloscope screen with the required DC scope input. Also, variations only between 1.5 seconds to 110 milliseconds are observed, and a sensitivity of 0.015% per 10 millimeters of deflection can be expected with this test unit. An internal calibrator which changes the signal by a percentage corresponding to an input amplitude change of the same amount was also incorporated in this tester. The output of the Model 52 Amplitude Stability Tester can be observed either on an oscilloscope or sensitive strip chart recorder.

4-3 Frequency Calibration

With the frequency counter and AC VTVM connected across the output, check the frequency calibration and amplitude at the following frequencies:

4-3.1 Decade Switch Calibration

Set the amplitude control on "direct" for 10.0 volts RMS at 1 KC. Do not readjust the amplitude control during the remainder of the frequency calibration. Below 10 cps, a DC coupled oscillo-

scope must be used to measure the amplitude.

Frequency Setting	Tolerance Frequency	Tolerance Amplitude	Remedy Frequency Off Tolerance	Remedy Amplitude Low*
99.9 KC	± 3%	± 0.1 db	Adjust C102	
10.0 KC	± 1%	± 0.01 db	Adjust C309A	Increase C308 and decrease C309
11.1 KC	± 3%	± 0.1 db	Check Network Resistors	
22.2 KC	± 3%	± 0.1 db	" "	"
33.3 KC	± 3%	± 0.1 db	" "	"
1.00 KC	± 1%	± 0.01 db	Adjust C301A	Increase C310 and decrease C311
2.00 KC	± 1%	± 0.01 db	Check Network Resistors	
3.00 KC	± 1%	± 0.01 db	" "	"
4.00 KC	± 1%	± 0.01 db	" "	"
5.00 KC	± 1%	± 0.01 db	" "	"
6.00 KC	± 1%	± 0.01 db	" "	"
7.00 KC	± 1%	± 0.01 db	" "	"
8.00 KC	± 1%	± 0.01 db	" "	"
9.00 KC	± 1%	± 0.01 db	" "	"
9.99 KC	± 1%	± 0.01 db	" "	"
100 cps	± 1%	± 0.01 db	Adjust C316A	Increase C316 and decrease C315
999 cps	± 1%	± 0.01 db	Adjust C316A	Increase C316 and decrease C315
10.0 cps	± 1%	± 0.01 db	TRIM C312 and/or C313	Increase C313 and decrease C312
99.9 cps	± 1%	± 0.01 db	"	"
9.99 cps	± 1%	± 0.01 db	TRIM C307 and/or C314	Increase C307 and decrease C314
1.00 cps	± 3%	± 0.01 db	"	"

*NOTE: If amplitude is high, change capacitors in the opposite direction.

In correcting excessive errors in either frequency or amplitude, if the other function (amplitude or frequency respectively) is in error at all, changing only one of the two capacitors mentioned will correct both errors. If the frequency is low, decrease capacitors; if the frequency is high, increase capacitors. One

capacitor must be changed by twice the percent error or two capacitors each changed by the percent error. There is an adjustable trimmer capacitor installed across one of these capacitors on the X100, X10 and X1 multiplier positions.

To check the accuracy of the units and tens decade switches, check the frequency and amplitude with the range switch in the X100 position at the settings 010 through 090, and 001 through 009. The frequency tolerance on these switches is ± 3% and the amplitude tolerance is ± 0.25 db. If the frequency or amplitude is incorrect, check the network resistors.

4-3.2 Frequency Stability vs. Line Voltage

Check the frequency at 9.99 KC as the line voltage is changed from 115 volts to 105 volts and to 125 volts. Tolerance: Frequency ± 0.03% 1 cps to 10 KC; 0.2% to 100 KC for a ± 10% change in line voltage.

4-3.3 Frequency Vernier Check

With the frequency vernier set to OFF, set the oscillator push-buttons to 001 with the frequency multiplier on 10. The frequency should read 10 cps ± 1%, and the amplitude should be 10 volts ± 1 db. If the frequency is low, increase either R368 or R369 depending on whichever helps the amplitude in the proper direction. Turn the vernier clockwise until the counter reads 20 cps. The vernier knob should now read 10 ± 15%. If it does not, rotate the knob on the vernier shaft. If the amplitude is low at this point, decrease R365. Turn the vernier full clockwise. The frequency should be reading between 30 and 40 cps and the amplitude should be still 10 volts ± 1 db. If the frequency or amplitude is low, decrease R365 and repeat all of this step.

4-4 Distortion Measurement

The distortion measurement should be made with a line voltage of 115 volts having less than 1% distortion unless otherwise specified.

4-4.1 AVC Amplifier Distortion

Set the oscillator to 20 cps. Connect the scope to Pin 8 of V3 (6V6). The signal should be between 3 to 5.5 volts and not noticeably distorted. If the signal is distorted, change V1, V2 or V3. Repeat at 99.9 KC frequency setting.

4-4.2 Output Amplifier Distortion

Connect the scope to Pin 7 of V5 (12AX7A). Signal should be between 25 to 90 millivolts RMS and not noticeably distorted. If distortion is excessive, adjust R213.

4-4.3 Oscillator Distortion

Using either a wave analyzer or distortion meter proceed to measure the distortion of the oscillator at the following frequencies. Measure the distortion with and without a 2000 ohm resistive load in the "direct" output mode.

Frequency	Tolerance
50 KC	Less than 0.1%
400 cps - 5 KC	Less than 0.02%
20 cps	Less than 0.2%

If the signal is distorted, change V9, (5V4).

4-5 Hum Content

Use the wave analyzer or distortion meter set to measure hum. Tolerance: Less than 0.02%.

4-6 Amplitude Stability

Changes in output amplitude can be readily measured with the high sensitivity of the Holt Model 52 Amplitude Stability Tester.

4-6.1 General Stability

The amplitude stability after one hour warmup period is better than 0.01% short term.

The amplitude stability vs. frequency is constant within ± 0.01 db (0.1%) over the frequency range from 1 cps to 10 KC; within ± 0.1 db (1%) from 10 KC to 100 KC.

4-6.2 Amplitude Stability vs. Line Voltage

Check the amplitude at 9.99 KC as the line voltage is changed from 115 volts to 105 volts and 125 volts. Tolerance: Amplitude ± 0.01 % for a ± 10% change in line voltage.

4-6.3 Hum Modulation

Set the oscillator frequency to 58 cps, and observe any amplitude modulation of the sine wave. Repeat at 59, 60, 61 and 62 cps. Tolerance: Less than 0.1 % modululation.

If incorrect, change V1 or V2, or adjust the hum flux loops.

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corporation	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee 4, Wis.
C	Amperite Company	New York, N.Y.
D	Arrow, Hart, & Hegeman	Hartford, Conn.
E	Arco-Elmenco	New York 13, N.Y.
F	American Spring & Wire Co.	Chicago, Ill.
G	Bowmar Instrument Lab	Fort Wayne, Ind.
H	Centralab	Milwaukee 1, Wis.
HIL	Holt Instrument Labs	Oconto, Wis.
I	Chicago Standard Trans Corp	Chicago, Ill.
J	Cornish Wire Co.	New York 7, N.Y.
K	Daven	Livingston, N.J.
L	Daystrom Pacific	Los Angeles, Calif.
M	Drake	Chicago, Ill.
N	Electro Instruments, Inc.	San Diego, Calif.
O	Eldema Corp.	El Monte, Calif.
P	Electron Prod.	Pasadena, Calif.
Q	Good-All Electric Mfg. Co.	Ogallala, Nebr.
R	General Electric	Schenectady, N.Y.
S	General Radio	West Concord, Mass.
T	Guardian Electric	Chicago, Ill.
U	Hoffman Semi-Conductor	Evanston, Ill.
V	Hughes Semi-Conductor Corp.	Oceanside, Calif.
W	International Rectifier Corp.	El Segundo, Calif.
X	International Resistance Co.	Philadelphia 8, Pa.
Y	James Vibrapowr	Chicago, Ill.
Z	Any brand tube meeting RETMA characteristics	
AA	Bunting Brass & Bronze Co.	Toledo 1, Ohio
BB	Little Fuse	Des Plaines, Ill.
CC	Mallory & Co.	Indianapolis, Ind.
DD	Northern Engineering Lab	Burlington, Wis.
EE	Oak Mfg. Co.	Chicago, Ill.
FF	Ohmite	Skokie, Ill.
GG	Raytheon	Newton, Mass.
HH	Rotron Mfg. Co.	Woodstock, N.Y.
II	Sage Electronics	East Rochester, N.Y.
JJ	Switchcraft	Chicago 30, Ill.
KK	Spectrol Electronics	San Gabriel, Calif.
LL	SNC Transformer Corp.	Oshkosh, Wis.
MM	Southern Electronics	Burbank, Calif.
NN	Sprague	North Adams, Mass.
OO	Sarkes Tarzian	Bloomington, Ill.
PP	Stancor	Chicago, Ill.
QQ	Topaz Products, Inc.	San Diego, Calif.
RR	Weston	Newark, N.J.
SS	Beckman Instruments	Fullerton, Calif.
TT	Nucleonics Products Corp.	Los Angeles, Calif.
UU	Miller, J. W.	Los Angeles, Calif.
VV	Triad Transformer Co.	Venice,Calif.
WW	Radio Condenser Co.	Camden, N.J.
XX	Texas Instrument	Dallas, Texas
YY	Pacific Semiconductor	Culver City, Calif.
ZZ	Leeds & Northrup Co.	Philadelphia, Pa.
AB	Vacuum Products	Mt. Vernon, N.Y.
AC	Corning-Glass Works	Bradford, Pa.

CODE LETTER	MANUFACTURER	ADDRESS
AD	Diehl Manufacturing Co.	Finderne, N.J.
AE	Astron Corporation	E. Newark, N.J.
AF	Chicago Condenser	Chicago, Ill.
AG	Elco Sales Co.	Philadelphia, Pa.
AH	Millen, James - Mfg.	Malden, Mass.
AI	Cornell-Dubilier Electric Corp.	South Plainfield, N.J.
AJ	Bendix AViation Corp.	Long Branch, N.J.
AK	Sylvania Electric Products Inc.	New York, N.Y.
AL	Motorola Inc.	Phoenix, Arizona
AM	Amphenol Electronics Corp.	Chicago, Ill.
AN	Phaostron Inst. & Electronics Co.	South Pasadena, Calif.
AO	Winchester Electronics Inc.	Norwalk, Conn.
AP	Filtors Inc.	Port Washington, N.Y.
AQ	United Transformer Corp.	New York, N.Y.
AR	Dayton Electric Mfg. Co.	Chicago, Ill.
AS	Advance Relays	Burbank, Calif.
AT	Fenwal, Inc.	Ashland, Mass.
AU	H-B Instrument Co.	Philadelphia, Pa.
AV	Thordarson, Meissner	Mt. Carmel, Ill.
AW	Dialight Corp.	Brooklyn, N.Y.
AX	General Instrument Corp.	Newark, N.J.
AY	Tru-Ohm Products	Chicago, Ill.
AZ	Dale Electronics, Inc.	Columbus, Nebr.
BA	Clarostat Mfg. Co., Inc.	Dover, N.H.
BC	Bourns, Inc.	Riverside, Calif.
BD	General Transistor Corp.	Jamaica, N.Y.
BE	Clevite Corp.	Bedford, Ohio
BF	Carling Electric Inc.	West Hartford, Conn.
BG	Bird Electronics Corp.	Cleveland, Ohio
BH	Cardwell Electronic Productions	Plainville, Conn.
BI	Shallcross Mfg. Co.	Selma, N.C.
BJ	NJE Corp.	Kenilworth, N.J.
BK	Vogue Instrument Corp.	Brooklyn, N.Y.
BL	The Eppley Laboratory, Inc.	Newport, R.I.
BM	Conelco	Monrovia, Calif.
BN	Relay Sales	Oak Park, Ill.
BO	Electro Scientific Industries	Portland, Ore.
BP	Cannon Electric Co.	Los Angeles, Calif.
BQ	Superior Electric Co.	Bristol, Conn.
BR	C. P. Clare & Co.	Chicago, Ill.
BS	Sola Electric Co.	Elk Grove Village, Ill.
BT	Tresco, Inc.	Philadelphia, Pa.
BU	Ultronix, Inc.	San Mateo, Calif.
BV	Heyman Mfg. Co.	Kenilworth, N.J.
BW	Cinch Mfg. Co.	Chicago, Ill.
BX	Alden Products Co.	Brockton, Mass.
BY	Jan Engineering Co.	Santa Monica, Calif.
BZ	Ovenaire Inc.	Charlottesville, Va.
CA	Atohm Electronics	Sun Valley, Calif.
CB	Mossman-Elliot	Joliet, Ill.
CD	Illinois Condenser Co.	Chicago, Ill.
CE	Bussman Mfg. Co.	St. Louis, Mo.
CF	Cinema Engineering	Burbank, Calif.
CG	Chicago Telephone Supply Corp.	Elkhart, Ind.
CH	Cutler-Hammer Inc.	Milwaukee, Wis.

CODE LETTER	MANUFACTURER	ADDRESS
CI	Krohn-Hite Corp.	Cambridge, Mass.
CJ	Resistors, Inc.	Chicago, Ill.
CK	Tru-Connector Corp.	Lynn, Mass.
CL	Ucinite Co.	Newtonville, Mass.
CM	Ward Leonard Electric Co.	Chicago, Ill.
CN	Milwaukee Transformer Co.	Milwaukee, Wis.
CO	Magnecraft Electric Co.	Chicago, Ill.

Ckt. Ref.	Description	Mfr. & Mfr. Designation
C100	Part of Z101	
C101	Capacitor, Fixed, Dur-Mica 330 MMF, 500 VDC, ± 20%	E DM-15-331M
C102	Capacitor, Variable, Mica 1-7 MMF, 175 VDC	E 400
C103	Capacitor, Fixed, Tubular .47 MFD, 200 VDC, ± 20%	NN 67P47402
C104	Capacitor, Fixed, Ceramic .02 MFD, 500 VDC, ± 20%	NN 36C201A
C105	Capacitor, Fixed, Dur-Mica 220 MMF, 500 VDC, ± 20%	E DM-15-221M
C106	Capacitor, Fixed, Dur-Mica 18 MMF, 500 VDC, ± 20%	E DM-15-180M
C107	Capacitor, Fixed, Dur-Mica 100 MMF, 500 VDC, ± 20%	E DM-15-101M
C108	Capacitor, Fixed, Ceramic .02 MFD, 500 VDC, ± 20%	NN 36C201A
C109	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C110	Capacitor, Fixed, Dur-Mica 4.7 MMF, 500 VDC, ± 20%	E DM-15
C201	Capacitor, Fixed, Ceramic .01 MFD, 500 VDC, ± 20%	NN 29C9B6
C202	Capacitor, Fixed, Dur-Mica 24 MMF, 500 VDC, ± 20%	E DM-15-240M
C203	Capacitor, Fixed, Dur-Mica 39 MMF, 500 VDC, ± 5%	E DM-15-390J
C204	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C205	Capacitor, Fixed, Ceramic .02 MFD, 500 VDC, ± 20%	NN 36C201A
C206	Capacitor, Fixed, Ceramic .01 MFD, 500 VDC, ± 20%	NN 29C9B6
C207	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A

Ckt. Ref.	Description	Mfr. & Mfr. Designation
C208	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C209	Capacitor, Fixed, Ceramic .02 MFD, 500 VDC, ± 20%	NN 36C201A
C210	Capacitor, Fixed, Tubular .01 MFD, 600 VDC, ± 20%	NN 73P10306
C211	Capacitor, Fixed, Mica 470 MMF, 500 VDC, ± 20%	E CM-19C-471M
C301A	Capacitor, Fixed, Mica 3.3 MMF, 500 VDC, ± 10%	E CM-19C
C301B	Capacitor, Fixed, Mica 4.7 MMF, 500 VDC, ± 10%	E CM-19C
C303	Capacitor, Fixed, Mica 18 MMF, 500 VDC, ± 10%	E CM-19C-180K
C304	Capacitor, Fixed, Mica 5.1 MMF, 500 VDC, ± 10%	E CM-19C
C306A	Capacitor, Fixed, Dur-Mica 39 MMF, 500 VDC, ± 20%	E DM-15-390M
*C307	Capacitor, Fixed, Met. Mylar 10 MFD, 75 VDC, ± 1%	AI MFT 104
C308	Capacitor, Fixed, Mica 1100 MMF, 500 VDC, ± 1%	E CM-25D-112E
C309	Capacitor, Fixed, Mica 800 MMF, 500 VDC, ± 5%	E CM-25C-801J
C309A	Capacitor, Variable, Mica 8-60 MMF, 175 VDC	E 404
*C310	Capacitor, Fixed, Tubular .01 MFD, 100 VDC, ± 1%	AI BCM 101
C310A	Capacitor, Variable, Mica 37-250 MMF, 175 VDC	E 426
*C311	Capacitor, Fixed, Tubular .01 MFD, 100 VDC ± 1%	AI BCM 101
*C312	Capacitor, Fixed, Met. Mylar 1 MFD, 200 VDC, ± 1%	AI MFIII

*NOTE: Frequency determining capacitors have a basic tolerance of ± 5%. They are selected and trimmed at the factory for proper frequency and amplitude calibration.

Ckt. Ref.	Description	Mfr. & Mfr. Designation
*C313	Capacitor, Fixed, Met. Mylar 1 MFD, 200 VDC, ± 1%	AI MF 111
*C314	Capacitor, Fixed, Met. Mylar 10 MFD, 75 VDC, ± 1%	AI MFT 104
*C315	Capacitor, Fixed, Tubular .1 MFD, 100 VDC, ± 1%	AI BCM 100
*C316	Capacitor, Fixed, Tubular .1 MFD, 100 VDC, ± 1%	AI BCM 100
C316A	Capacitor, Variable, Mica 1400-3055 MMF, 250 VDC	E 315
C400	Capacitor, Fixed, Ceramic .01 MFD, 500 VDC, ± 20%	NN 29C9B6
C401	Capacitor, Fixed, 4 MFD, 330 VAC, ± 20%	A P104J2
C401A	Capacitor, Fixed, .18 MFD, 400 VDC, ± 20%	NN 67P18404
C402	Capacitor, Fixed, 4 MFD, 330 VAC, ± 20%	A P104J2
C403	Capacitor, Fixed, Ceramic .01 MFD, 500 VDC, ± 20%	NN 29C9B6
C404	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C405	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C406	Capacitor, Fixed, Ceramic .001 MFD, 500 VDC, ± 20%	NN 40C230A
C407	Capacitor, Fixed, Electrolytic 20 MFD, 450 VDC,	NN TVA-1709
C408	Capacitor, Fixed, Electrolytic 20 MFD, 450 VDC	NN TVA-1709
C409	Capacitor, Fixed, Ceramic .02 MFD, 500 VDC, ± 20%	NN 36C201A
C410	Capacitor, Fixed, Dur-Mica 10 MMF, 500 VDC, ± 20%	E DM-15-100M
C411	Capacitor, Fixed, Ceramic .01 MFD, 500 VDC, ± 20%	NN 29C9B6

*NOTE: Frequency determining capacitors have a basic tolerance of ± 5%. They are selected and trimmed at the factory for proper frequency and amplitude calibration.

Ckt. Ref.	Description	Mfr. & Mfr. Designation
C601	Capacitor, Fixed Electrolytic, Dual 2 X 1000 MFD, 35 VDC	NN D29421
CR601	Diode, Silicon, Low Current 25 MA, 50 PIV	IN536
F401	Fuse, Slo- Blo 2 A	CE MDL-2
I401	Lamp, Indicating, 6.3 V, 61 MA, 2000 hrs	M 765
J101	Connector, Jack	CL 119278
J102	Connector, Jack	CL 119278
J103	Connector, Receptacle, BNC	CK TRU 378
J900	Connector, Receptacle, Binding Post Red	BQ DF 30RC
J901	Connector, Receptacle, Binding Post Black	BQ DF30BC
L401	Choke, 8hy at 150 ma	CI C-100-8
P101	Resistor, Variable, 5 KΩ, 2 Watt	B 30703
P102	Resistor, Variable 100 KΩ	B 40576
P202	Resistor, Variable 100 KΩ, 2 Watt	B 40576
P301	Assembly, Vernier Consisting of: Resistor, Fixed, Composition, Factory Selected Value, R368, R369 Resistor, Variable, Composition, Dual Section P301, 10 Megohm/10Megohm	CI 446-AR-P301
P401	Resistor, Variable 500 Ω	CG JF7516
P402	Line Cord, NEMA approved 3 Conductor	CI 4018
Q601	Transistor, Germanium, NPN	2N214

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R100	Part of Z101	
R102	Resistor, Fixed, Wire Wound 700 Ω, 1/2 Watt, ± 1%	K R-615
R104	Resistor, Fixed, Wire Wound 5.3 KΩ, 1/2 Watt, ± 1%	K R-615
R105	Resistor, Fixed, Composition 1.2 MΩ, 1/2 Watt, ± 5%	B EB 1255
R106	Resistor, Fixed, Composition 22 KΩ, 1/2 Watt, ± 5%	B EB 2235
R107	Resistor, Fixed, Composition 39 KΩ, 1/2 Watt, ± 10%	B EB 3931
R108	Resistor, Fixed, Composition 82 KΩ, 1/2 Watt, ± 10%	B EB 8231
R109	Resistor, Fixed, Composition 4.7 MΩ, 1/2 Watt, ± 5%	B EB 4755
R110	Part of Z101	
R111	Resistor, Fixed, Wire Wound 49 KΩ, 5 Watt, ± 1%	K R-626
R112	Resistor, Fixed, Wire Wound 3.5 KΩ, 1/2 Watt, ± 1%	K R-615
R113	Part of Z101	
R115	Resistor, Fixed, Composition 910 KΩ, 1/2 Watt, ± 5%	B EB 9145
R116	Resistor, Fixed, Composition 22 KΩ, 1/2 Watt, ± 5%	B EB 2235
R117	Resistor, Fixed, Metal Film 221 KΩ, 1/2 Watt, ± 10%	X MEC
R118	Resistor, Fixed, Composition 150 KΩ, 1/2 Watt, ± 10%	B EB 1541
R119	Resistor, Fixed, Wire Wound 12 KΩ, 3 Watt, ± 1%	AZ RS-2B
R120	Resistor, Fixed, Composition 2.7 MΩ, 1/2 Watt, ±5%	B EB 2755
R121	Resistor, Fixed, Wire Wound 1.58 KΩ, 1/2 Watt, ± 1%	K R-615

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R122	Resistor, Fixed, Composition 2 MΩ, 1/2 Watt, ± 5%	B EB 2055
R123	Resistor, Fixed, Wire Wound, Tapped 9.1 KΩ, 55 Watt	CI 440-AR-R123
R123A	Part of R123 5.1 KΩ	
R123B	Part of R123 4 KΩ	
R124	Resistor, Fixed, Composition 3 MΩ, 1/2 Watt, ± 5%	B EB 3055
R125	Resistor, Fixed, Composition 1.5 KΩ, 1/2 Watt, ± 10%	B EB 1521
R126	Resistor, Fixed, Wire Wound 12 KΩ, 2 Watt, ± 1%	II SA2W
R127	Resistor, Fixed, Metal Film 909 KΩ, 1/2 Watt, ± 1%	X MEC
R129	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R130	Resistor, Fixed, Metal Film 1.13 MΩ, 1/2 Watt, ± 1%	X MEC
R131	Factory Adjusted Approximately 100 KΩ	
R132	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R133	Resistor, Fixed, Wire Wound 17.5 KΩ, 2 Watt, ± 1%	II SA2W
R134	Resistor, Fixed, Composition 1.8 MΩ, 1/2 Watt, ± 5%	B EB 1855
R135	Resistor, Fixed, Composition 1.2 MΩ, 1/2 Watt, ± 5%	B EB 1255
R136	Part of Z101	
R201	Resistor, Fixed, Composition 220 KΩ, 1/2 Watt, ± 5%	B EB 2245
R202	Resistor, Fixed, Composition 220 KΩ, 1/2 Watt, ± 5%	B EB 2245
R203	Resistor, Fixed, Composition 1.2 MΩ, 1/2 Watt, ± 10%	B EB 1251

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R204	Resistor, Fixed, Metal Film 1.5 MΩ, 1/2 Watt, ± 1%	X MEC
R205	Resistor, Fixed, Composition 300 KΩ, 1/2 Watt, ± 5%	B EB 3045
R206	Resistor, Fixed, Composition 470 Ω, 1/2 Watt, ± 10%	B EB 4711
R207	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R208	Resistor, Fixed, Metal Film 1.05 MΩ, 1/2 Watt, ± 1%	X MEC
R209	Resistor, Fixed, Composition 27 KΩ, 1 Watt, ± 10%	B GB 2731
R210	Resistor, Fixed, Composition 12 KΩ, 2 Watt, ± 10%	B HB 1231
R211	Resistor, Fixed, Composition 27 KΩ, 1 Watt, ± 10%	B GB 2731
R212	Resistor, Fixed, Composition 18 KΩ, 1/2 Watt, ± 10%	B EB 1831
R213	Resistor, Fixed, Composition 820 KΩ, 1/2 Watt, ± 5%	B EB 8245
R214	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R215	Resistor, Fixed, Metal Film 56 KΩ, 1/2 Watt, ± 1%	X MEC
R216	Resistor, Fixed, Metal Film 120 KΩ, 1/2 Watt, ± 1%	X MEC
R217	Resistor, Fixed, Composition 1 MΩ, 1/2 Watt, ± 5%	B EB 1055
R218	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R219	Resistor, Fixed, Composition 1 MΩ, 1/2 Watt, ± 10%	B EB 1051
R220	Resistor, Fixed, Composition 470 KΩ, 1/2 Watt, ± 10%	B EB 4741
R221	Resistor, Fixed, Wire Wound 4 KΩ, 20 Watt, ± 5%	CM 20 [illegible],000WL

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R301	Resistor, Fixed, Deposited Carbon 5.423 MΩ, 1 Watt, ± 1/2%	X DCF
R302	Resistor, Fixed, Deposited Carbon 5.036 MΩ, 1 Watt, ± 1/2%	X DCF
R303	Resistor, Fixed, Deposited Carbon 5.036MΩ, 1 Watt, ± 1/2%	X DCF
R304	Resistor, Fixed, Deposited Carbon 2.611 MΩ, 1/2 Watt, ± 1/2%	X DCC
R305	Resistor, Fixed, Deposited Carbon 2.518 MΩ, 1/2 Watt, ± 1/2%	X DCC
R306	Resistor, Fixed, Deposited Carbon 2.518 MΩ, 1/2 Watt, ± 1/2%	X DCC
R307	Resistor, Fixed, Deposited Carbon 1.72 MΩ, 1/2 Watt, ± 1/2%	X DCC
R308	Resistor, Fixed, Deposited Carbon 1.679 MΩ, 1/2 Watt, ± 1/2%	X DCC
R309	Resistor, Fixed, Deposited Carbon 1.679 MΩ, 1/2 Watt, ± 1/2%	X DCC
R311	Resistor, Fixed, Deposited Carbon 542.3 KΩ, 1/2 Watt, ± 1/2%	X DCC
R312	Resistor, Fixed, Deposited Carbon 503.6 KΩ, 1/2 Watt, ± 1/2%	X DCC
R313	Resistor, Fixed, Deposited Carbon 503.6 KΩ, 1/2 Watt, ± 1/2%	X DCC
R314	Resistor, Fixed, Deposited Carbon 261.1 KΩ, 1/2 Watt, ± 1/2%	X DCC
R315	Resistor, Fixed, Deposited Carbon 251.8 KΩ, 1/2 Watt, ± 1/2%	X DCC
R316	Resistor, Fixed, Deposited Carbon 251.8 KΩ, 1/2 Watt, ± 1/2%	X DCC
R317	Resistor, Fixed, Deposited Carbon 172 KΩ, 1/2 Watt, ± 1/2%	X DCC
R318	Resistor, Fixed, Deposited Carbon 167.9 KΩ, 1/2 Watt, ± 1/2%	X DCC
R319	Resistor, Fixed, Deposited Carbon 167.9 KΩ, 1/2 Watt, ± 1/2%	X DCC

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R321	Resistor, Fixed, Deposited Carbon 506 KΩ, 1/2 Watt, ± 1/2%	X DCC
R322	Resistor, Fixed, Deposited Carbon 503.6 KΩ, 1/2 Watt, ± 1/2%	X DCC
R323	Resistor, Fixed, Deposited Carbon 503.6 KΩ, 1/2 Watt, ± 1/2%	X DCC
R324	Resistor, Fixed, Deposited Carbon 251.8 KΩ, 1/2 Watt, ± 1/2%	X DCC
R325	Resistor, Fixed, Deposited Carbon 251.8 KΩ, 1/2 Watt, ± 1/2%	X DCC
R326	Resistor, Fixed, Deposited Carbon 251.8 KΩ, 1/2 Watt, ± 1/2%	X DCC
R327	Resistor, Fixed, Deposited Carbon 167.9 KΩ, 1/2 Watt, ± 1/2%	X DCC
R328	Resistor, Fixed, Deposited Carbon 167.9 KΩ, 1/2 Watt, ± 1/2%	X DCC
R329	Resistor, Fixed, Deposited Carbon 167.9 KΩ, 1/2 Watt, ± 1/2%	X DCC
R331	Resistor, Fixed, Deposited Carbon 50.6 KΩ, 1/2 Watt, ± 1/2%	X DCC
R332	Resistor, Fixed, Deposited Carbon 50.36 KΩ, 1/2 Watt, ± 1/2%	X DCC
R333	Resistor, Fixed, Deposited Carbon 50.36 KΩ, 1/2 Watt, ± 1/2%	X DCC
R334	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R335	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R336	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R337	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC
R338	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC
R339	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC

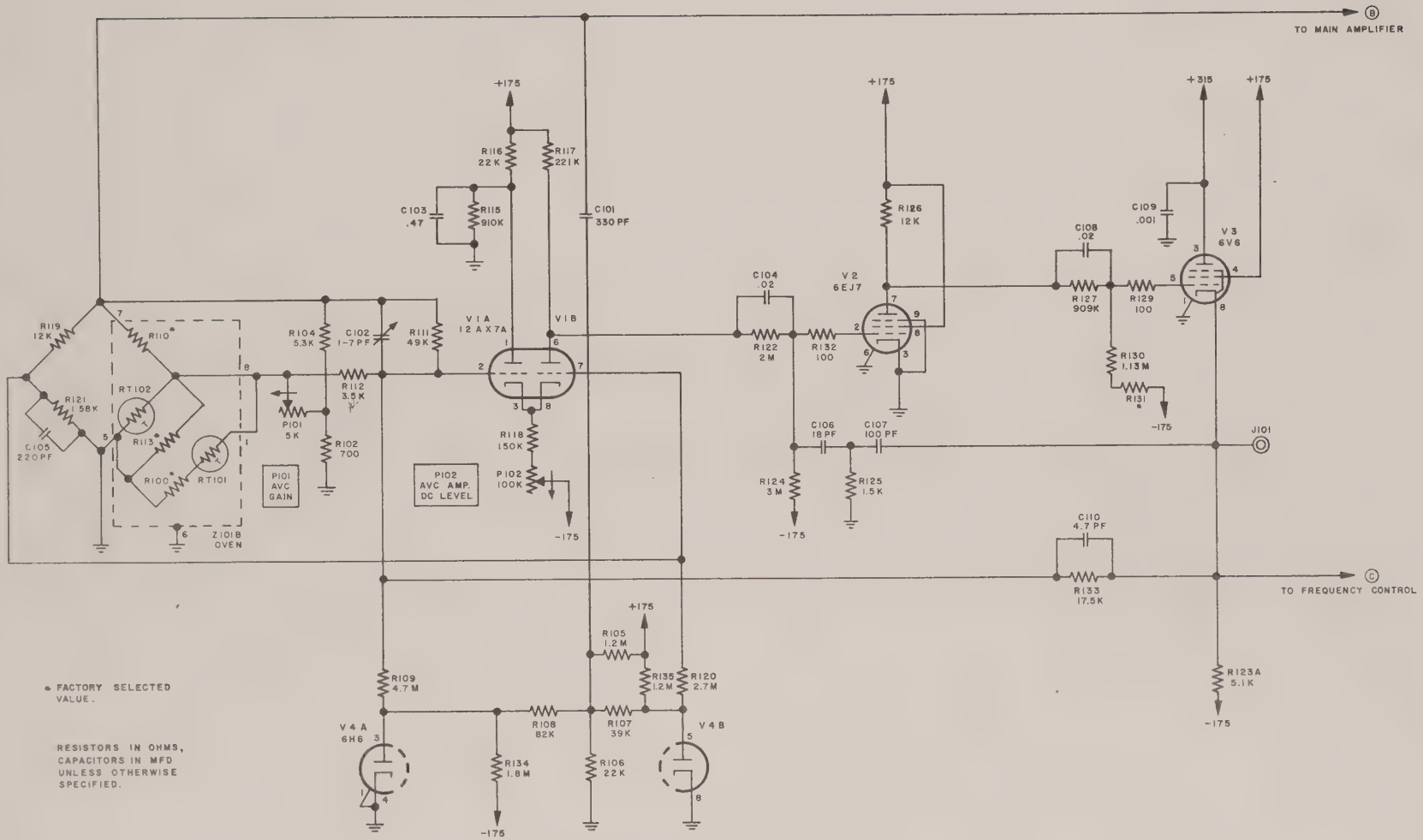
Ckt. Ref.	Desdription	Mfr. & Mfr. Designation
R341	Resistor, Fixed, Deposited Carbon 50.36 KΩ, 1/2 Watt, ± 1/2%	X DCC
R342	Resistor, Fixed, Deposited Carbon 50.36 KΩ, 1/2 Watt, ± 1/2%	X DCC
R343	Resistor, Fixed, Deposited Carbon 50.36 KΩ, 1/2 Watt, ± 1/2%	X DCC
R344	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R345	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R346	Resistor, Fixed, Deposited Carbon 25.18 KΩ, 1/2 Watt, ± 1/2%	X DCC
R347	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC
R348	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC
R349	Resistor, Fixed, Deposited Carbon 16.79 KΩ, 1/2 Watt, ± 1/2%	X DCC
R351	Resistor, Fixed, Deposited Carbon 5.030 KΩ, 1/2 Watt, ± 1/2%	X DCC
R352	Resistor, Fixed, Deposited Carbon 5.030 KΩ, 1/2 Watt, ± 1/2%	X DCC
R353	Resistor, Fixed, Deposited Carbon 5.030 KΩ, 1/2 Watt, ± 1/2%	X DCC
R354	Resistor, Fixed, Deposited Carbon 2.512 KΩ, 1/2 Watt, ± 1/2%	X DCC
R355	Resistor, Fixed, Deposited Carbon 2.512 KΩ, 1/2 Watt, ± 1/2%	X DCC
R356	Resistor, Fixed, Deposited Carbon 2.512 KΩ, 1/2 Watt, ± 1/2%	X DCC
R357	Resistor, Fixed, Deposited Carbon 1.671 KΩ, 1/2 Watt, ± 1/2%	X DCC
R358	Resistor, Fixed, Deposited Carbon 1.671 KΩ, 1/2 Watt, ± 1/2%	X DCC
R359	Resistor, Fixed, Deposited Carbon 1.671 KΩ, 1/2 Watt, ± 1/2%	X DCC

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R360	Resistor, Fixed, Composition 220 KΩ, 1/2 Watt, ± 10%	B EB 2241
R361	Resistor, Fixed, Composition 1.5 KΩ, 1/2 Watt, ± 10%	B EB 1521
R362	Resistor, Fixed, Composition 27 KΩ, 2 Watt, ± 10%	B HB 2731
R363	Resistor, Fixed, Composition 180 KΩ, 1/2 Watt, ± 5%	B EB 1845
R364	Resistor, Fixed, Composition 1.8 MΩ, 1/2 Watt, ±5%	B EB 1855
R365	Resistor, Fixed, Composition 180 KΩ, 1/2 Watt, ± 5%	B EB 1845
R368	Part of P301	
R369	Part of P301	
R400	Resistor, Fixed, Composition 2.2 KΩ, 1/2 Watt, ± 10%	B EB 2221
R400A	Resistor, Fixed, Composition 120 KΩ, 1/2 Watt, ± 10%	B EB 1241
R401	Resistor, Fixed, Composition 470 KΩ, 1/2 Watt, ± 10%	B EB 4741
R402	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R403	Resistor, Fixed, Composition 6.8 KΩ, 1/2 Watt, ± 10%	B EB 6821
R404	Resistor, Fixed, Composition 1.8 MΩ, 1/2 Watt, ± 10%	B EB 1851
R405	Resistor, Fixed, Composition 1.2 MΩ, 1/2 Watt, ± 10%	B EB 1251
R406	Resistor, Fixed, Composition 220 KΩ, 1/2 Watt, ± 10%	B EB 2241
R407	Resistor, Fixed, Composition 330 KΩ, 1/2 Watt, ± 5%	B EB 3345
R408	Resistor, Fixed, Composition 330 KΩ, 1/2 Watt, ± 5%	B EB 3345
R409	Resistor, Fixed, Composition 18 KΩ, 2 Watt, ± 10%	B HB 1831

Ckt. Ref.	Description	Mfr. & Mfr. Designation
R410	Resistor, Fixed, Wire Wound 155 KΩ, 1/2 Watt, ± 1%	CF CE 252E
R411	Resistor, Fixed, Composition 220 KΩ, 1/2 Watt, ± 5%	B EB 2245
R412	Resistor, Fixed, Composition 2.4 MΩ, 1/2 Watt, ± 5%	B EB 2455
R413	Resistor, Fixed, Wire Wound 150 KΩ, 1/2 Watt, ± 1%	CF CE 252E
R413A	Resistor, Fixed, Composition 15 MΩ, 1/2 Watt, ± 5%	B EB 1565
R414	Resistor, Fixed, Composition 510 KΩ, 1/2 Watt, ± 5%	B EB 5145
R415	Resistor, Fixed, Composition 1.3 MΩ, 1/2 Watt, ± 5%	B EB 1355
R416	Resistor, Fixed, Composition 1.8 MΩ, 1/2 Watt, ± 5%	B EB 1855
R417	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R418	Resistor, Fixed, Wire Wound 4.5 KΩ, 30 Watt, ± 5%	CI 440-AR-R418
R419	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 20%	B EB 1012
R421	Resistor, Fixed, Wire Wound 1.4 KΩ, 5 Watt, ± 5%	CJ 5AX
R601	Resistor, Fixed, Composition 1.2 KΩ, 1/2 Watt, ± 5%	B EB 1225
R602	Resistor, Fixed, Composition 100 KΩ, 1/2 Watt, ± 10%	B EB 1041
R603	Resistor, Fixed, Composition 5.6 KΩ, 1/2 Watt, ± 5%	B EB 5625
R604	Resistor, Fixed, Composition 47 KΩ, 1 Watt, ± 10%	B GB 4731
R900A	Part of Z900	
R900B	Part of Z900	

Ckt. Ref.	Description	Mfr. & Mfr. Designation
RT 101	Part of Z101	
RT 102	Part of Z101	
S301	Switch, Push Button, 10 Gang	CI 440-S301
S302	Switch, Push Button, 10 Gang	CI 440-S301
S303	Switch, Push Button, 10 Gang	CI 440-S301
S304	Switch, Rotary, 5 Position	CI 446-AS4
S401	Switch, Toggle, SPST	CH 8280K16
S900A	Part of Z900	
S900B	Part of Z900	
T401	Transformer, Power	CI P-100-32
T900	Transformer, Output	HIL 11623
V1	Vacuum Tube, Electron	Z 12AX7A
V2	Vacuum Tube, Electron	Z 6EJ7/EF184
V3	Vacuum Tube, Electron	Z 6V6
V4	Vacuum Tube, Electron	Z 6H6
V5	Vacuum Tube, Electron	Z 12AX7A
V6	Vacuum Tube, Electron	Z 6EJ7/EF184
V7	Vacuum Tube, Electron	Z 6EJ7/EF184
V8	Vacuum Tube, Electron	Z 6AU5
V9	Vacuum Tube, Electron	Z 5V4

Ckt. Ref.	Description	Mfr. & Mfr. Designation
V10	Vacuum Tube, Electron	Z 6AU5
V11	Vacuum Tube, Electron	Z 6SL7
V12	Gas filled Tube, Electron	Z OG3
V13	Vacuum Tube, Electron	Z 6SL7
V14	Vacuum Tube, Electron	Z 6V6
Z101	Assembly, Oven Consisting of: Oven, 10 Watt, 117 VAC Capacitor, Fixed, C100, .02 MFD Resistor, Fixed, Factory Selected Value, R100, R110, R113 Resistor, Fixed, Composition, R136 22 Ω, 1/2 Watt, ± 10% Thermistor, Factory Selected RT101, RT102	CI KH-Z101
Z900	Assembly, Output Attenuator Consisting of: Resistor, Variable, Composition, Dual R900A, R900B, 5K/1KΩ, 1/2 Watt Switch, DPDT, S900A, S900B	HIL 10180-000



* FACTORY SELECTED VALUE.

RESISTORS IN OHMS, CAPACITORS IN MFD UNLESS OTHERWISE SPECIFIED.

EFFECTIVE SERIAL NO 5559

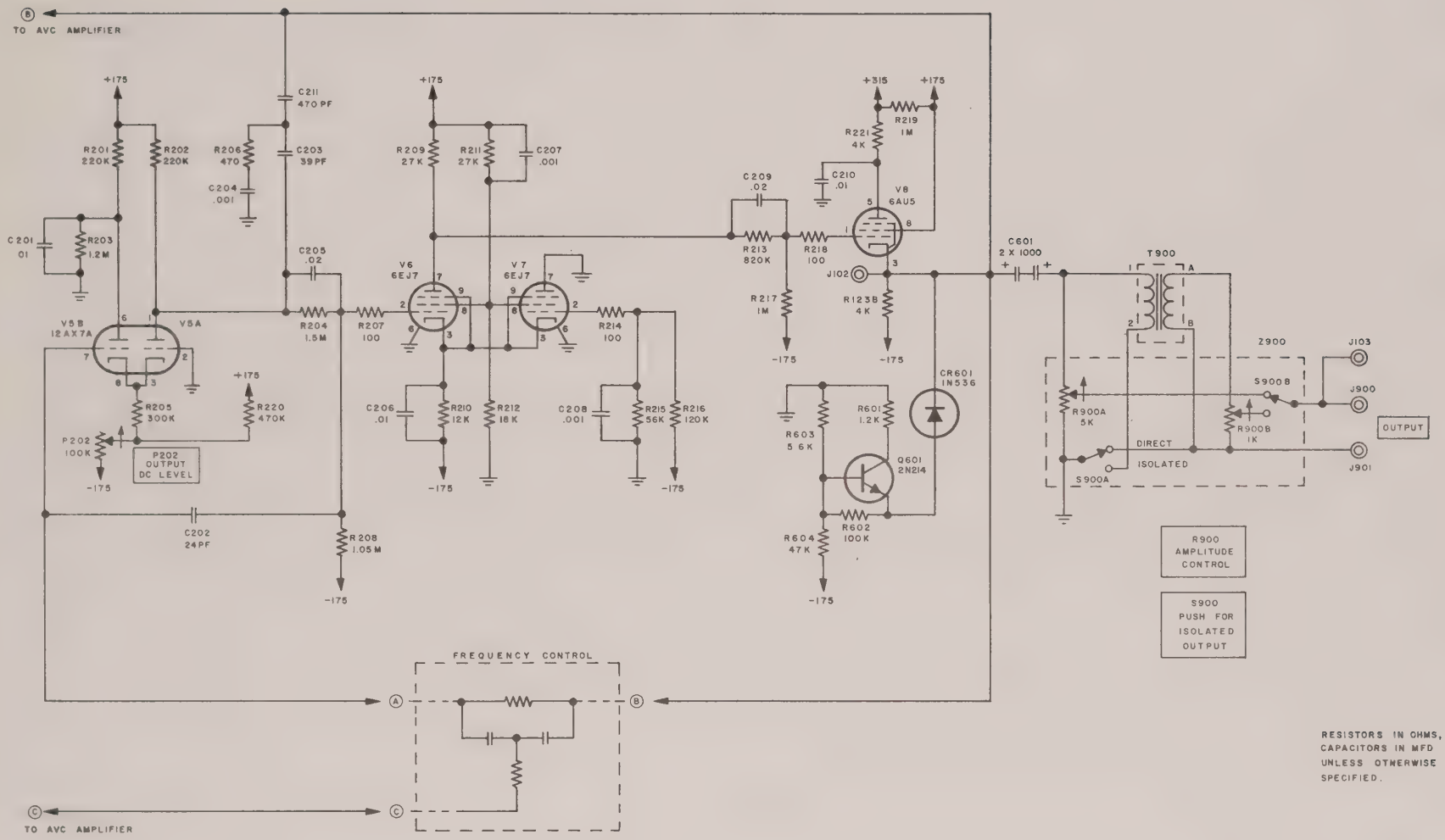
SCHEMATIC DIAGRAM

AVC AMPLIFIER

MODEL 448

HOLT INSTRUMENT LABORATORIES

OCONTO WISCONSIN



RESISTORS IN OHMS, CAPACITORS IN MFD UNLESS OTHERWISE SPECIFIED.

EFFECTIVE SERIAL NO. 5559

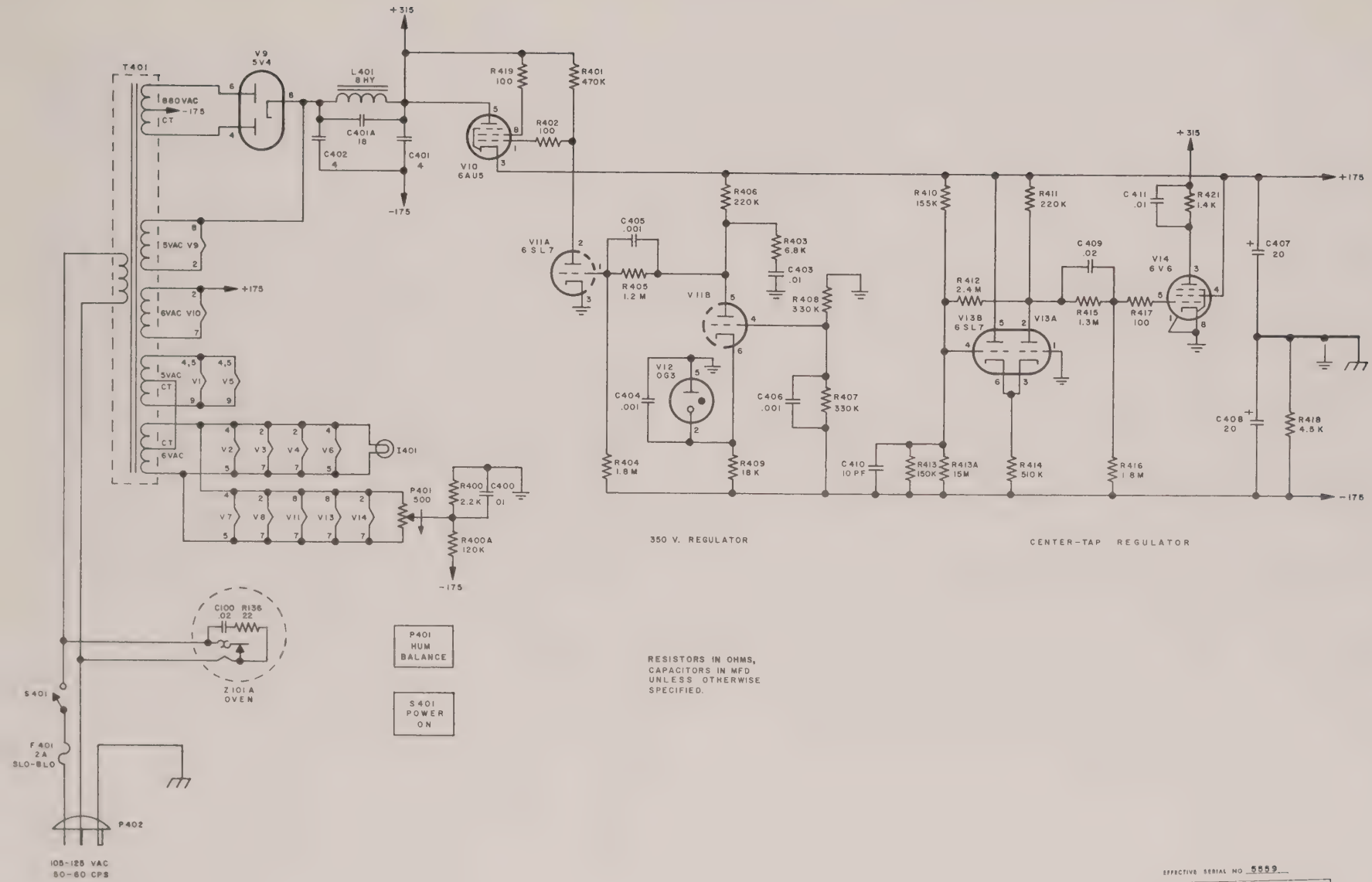
SCHEMATIC DIAGRAM

MAIN AMPLIFIER

MODEL 448

HOLT INSTRUMENT LABORATORIES

OCONTO WISCONSIN



RESISTORS IN OHMS,
CAPACITORS IN MFD
UNLESS OTHERWISE
SPECIFIED.

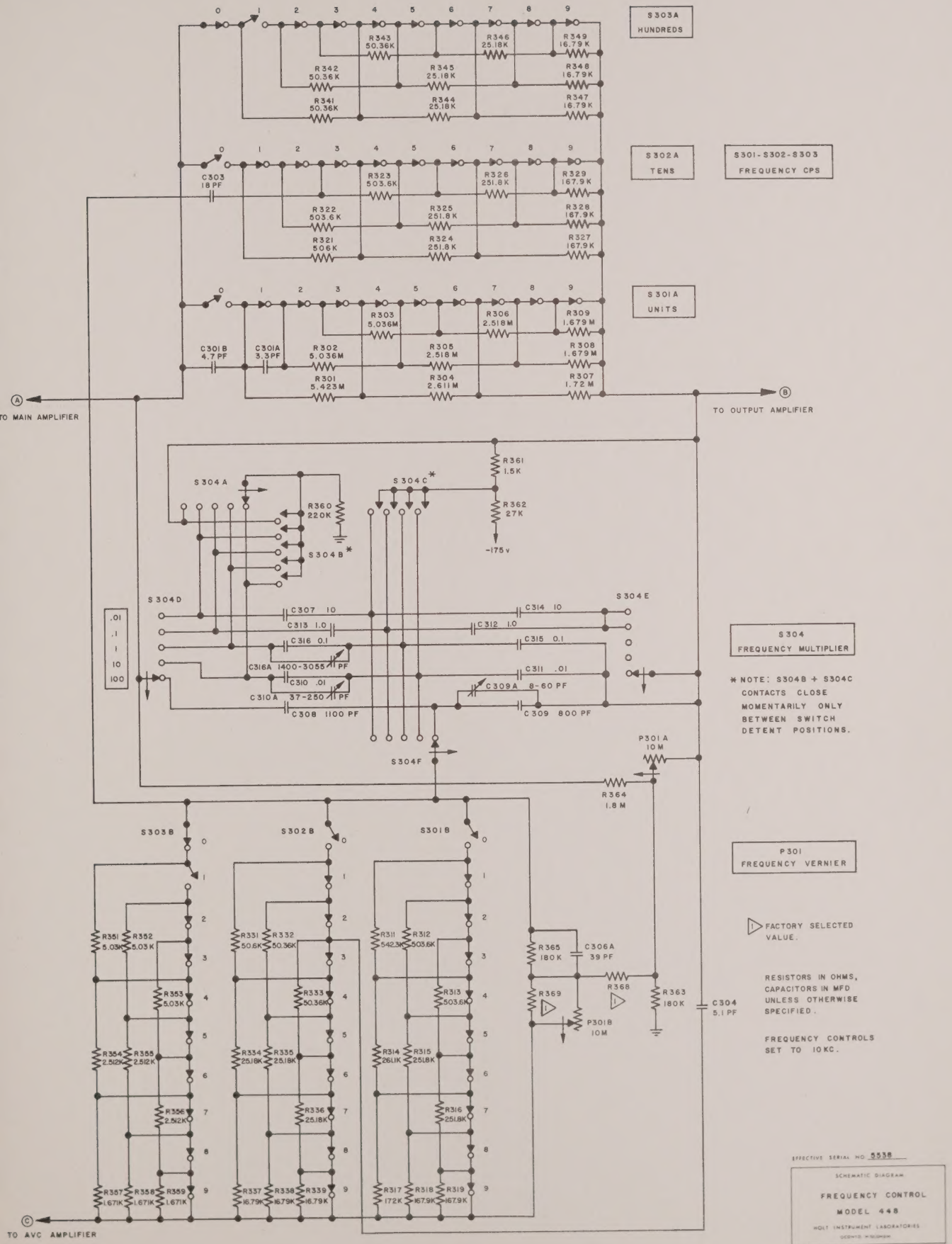
EFFECTIVE SERIAL NO 5559

SCHEMATIC DIAGRAM

POWER SUPPLY

MODEL 448

HOLT INSTRUMENT LABORATORIES



EFFECTIVE SERIAL NO 9538

SCHEMATIC DIAGRAM

FREQUENCY CONTROL

MODEL 448

HOLT INSTRUMENT LABORATORIES